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Relativistic Solar Particle Events Recorded by the Lomnicky Stit Neutron Monitor

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ABSTRACT

Using the cosmic radiation measurements obtained by the Lomnicky Stit neutron monitors since 1964, data recorded during each of the 38 reported relativistic solar cosmic ray events have been assembled. A summary of these measurements is given together with comments about the unique solar neutron measurements in 1982. Events in the 19th solar cycle are also discussed.

1. INTRODUCTION

Measurements of the cosmic ray intensity on Lomnicky Stit (49.20 N, 20.22 E, altitude 2634 meters, R_c ~4 GV) commenced in January 1958 as part of the Czechoslovakian scientific program associated with the International Geophysical Year (Dubinsky, 1960). The initial data were recorded in bi-hourly intervals in accordance with the guidelines established by the IGY Committee. Experience gained during the IGY and later years illustrated that smaller recording intervals were necessary for many transient studies; therefore, hourly data were routinely archived starting on 1 February 1968. The average counting rate of the IGY monitor was 9.10×10^4.

In January 1972 a 4-tube IQSY monitor with an hourly counting rate of 8.10×10^5 replaced the IGY monitor. This monitor was subsequently replaced in December 1981 by an 8-tube NM64 installed in the small house on the roof of the main building at Lomnicky Stit. The average hourly counting rate of the 8-tube monitor is 1.6×10^6. At each of these changes, both monitors were kept in concurrent operation for several months so that the recorded cosmic ray intensity could be normalized back to the initial measurements in 1958.

2. GROUND-LEVEL ENHANCEMENT DATABASE, 1964-1991

Table 1 lists the 38 ground-level cosmic ray enhancements (GLE) that have been recorded at the earth from 1964 until the end of 1991. Using data from the Lomnicky Stit archives and from other records available to us, the data were assembled in the standard GLE format (Shea et al., 1987) for each of the time periods when ground-level events had been reported. Five-minute data were available for all of the recent events; other time intervals are noted in the table. Each of the data sets were examined to determine the onset time of the enhancement, the time of maximum intensity and the magnitude of each event.

Table 1 also lists information on the solar flare associated with the particle event. We emphasize that care must be taken in using this table. For the events prior to 1971, solar flare information was obtained from Svestka and Simon (1975). For events after 1970, the group-line list of solar flares in Solar-Geophysical Data (published six months after the events) was used. The group line in SGD gives the earliest reported onset from all solar observations; this onset time may not reflect the majority of reports or the time of particle acceleration. Therefore, individual inspection of all solar emissions - H-alpha records, X-ray, and radio data should be made prior to analyses requiring accurate timing. Likewise, the position of the flare is a composite of the individual reports in SGD.

The onset times for each of the solar ground-level enhancements recorded at Lomnicky Stit were selected as the time period when it appeared that solar particles were first detected by the monitor. For rapid increases the onset times could be given within a five-minute interval; however, for slowly

PRELIMINARY EVALUATION OF THE LOMNICKY STIT NEUTRON MONITOR DATA FOR THE SOLAR GROUND-LEVEL ENHANCEMENTS FROM 1966 UNTIL JUNE 1991

Date	Flare Position	H-alpha Onset	IMP.	GLE Onset	GLE Maximum	Inc. (%)
7 Jul 66	35N, 48W	0025	2B	n.o.	n.o.	---[a]
28 Jan 67	~22N,~150W[b]	<02--	--	n.o.	n.o.	---[a]
28 Jan 67	~22N,~150W[b]	<08--	--	0715-0730	1000-1015	5.0[c]
29 Sep 68	17N, 51W	1617	2B	n.o.	n.o.	---[d]
18 Nov 68	21N, 87W	<1026	1B	n.o.	n.o.	---[c]
25 Feb 69	13N, 37W	0900	2B	0900-1000	0900-1000	1.3[d]
30 Mar 69	~19N,~103W[b]	<0332	1N	0600-0700	0700-1400	1.5[d,e]
24 Jan 71	18N, 49W	2215	3B	n.o.	n.o.	---[c,d*]
1 Sep 71	~11S,~120W[b]	<1934	--	2100-2200	2300-2400	2.1[c,d*]
4 Aug 72	14N, 8E	0617	3B	n.o.	n.o.	---
7 Aug 72	14N, 37W	1449	3B	1630-1650	1700-1710	1.9
29 Apr 73	14N, 73W	2056	2B	n.o.	n.o.	---[d]
30 Apr 76	8S, 46W	2047	1B	n.o.	n.o.	---[d]
19 Sep 77	8N, 57W	<0955	3B	n.o.	n.o.	---
24 Sep 77	~10N,~120W[b]	<0552	--	0645-0650	0940-0955	3.9
22 Nov 77	24N 40W	0945	2B	1015-1025	1035-1040	4.2
7 May 78	23N, 72W	0327	1N	0335-0340	0340-0345	32.9
23 Sep 78	35N, 50W	0944	3B	1000-1100	1100-1200	1.2[d]
21 Aug 79	17N, 40W	0550	2B	n.o.	n.o.	---[d,f]
10 Apr 81	7N, 36W	1632	2B	n.o.	n.o.	---
10 May 81	3N, 75W	0715	1N	n.o.	n.o.	---
12 Oct 81	18S, 31E	0615	2B	0650-0655	0755-0810	3.6
26 Nov 82	12S, 87W	0230	1N	0310-0315	0320-0430	1.5[g]
7 Dec 82	19S, 86W	2341	1B	2350-2355	0000-0005	9.1
16 Feb 84	S,~130W[b]	<0858.3	--	0905-0910	0910-0915	3.7
25 Jul 89	26N, 85W	0839	1B	n.o.	n.o.	---[h]
16 Aug 89	15S, 85W	0058	2N	0150-0155	0225-0230	2.6[i]
29 Sep 89	~24S,~105W[b]	1141	1B	1145-1150	1230-1245	178.3
19 Oct 89	25S, 9E	1229	3B	1330-1335	1430-1435	9.7
22 Oct 89	27S, 32W	1708	1N	1800-1805	1805-1810	1.5[g]
24 Oct 89	29S, 57W	1738	2N	1825-1830	1915-1920	22.2
15 Nov 89	11N, 28W	0638	2B	0700-0705	0700-0705	1.4
21 May 90	34N, 37W	2212	2B	2235-2240	2300-2315	5.1
24 May 90	36N, 76W	2046	1B	2100-2105	2115-2120	6.5
26 May 90	~35N,~103W[b]	2045.6	--	2205-2215	2210-2250	1.3[g]
28 May 90	~35N,~120W[b]	<0516	--	0500-0505		---[h]
11 Jun 91	32N, 15W	0105	2B	0230-0245	0440-0455	2.4
15 Jun 91	36N, 70W	0633	3B	0845-0855	0925-0935	3.6

Footnotes:

a. Bi-hourly values.
b. Flare behind the west limb of sun. Position estimated from location of assumed associated active region.
c. 10 or 15-minute values.
d. Only hourly data available.
e. Only 4 hours present in the 7 hour period.
f. Large modulation present.
g. Broad maximum; data averaged over the time period.
h. Slight enhancement; enhanced cosmic ray modulation present.
i. Slight enhancement.

n.o. Increase not observed.
* Two monitors in operation at this time.

rising or very small events the data were averaged for 10 or 15-minute intervals to determine the period in which a statistically significant increase was evident. The same procedure was used to determine the time of maximum intensity. For those events with a broad maximum, the data were averaged to determine the magnitude. The baseline from which the magnitude was determined was typically the hour before the onset in H-alpha.

The Lomnicky Stit monitor recorded 24 of the reported 38 ground-level enhancements with the largest event recorded on 29 September 1989 as illustrated in Figure 1. Since the vertical cutoff rigidity of the station is ~4 GV, we know that solar processes accelerated protons to at least 4 GV during each of those events. The advantage of a mountain station is in the statistics. Several of the events are relatively small with maximum intensity less than 5% for 16 of the events; however, many of these enhancements might not be discernible using data from a comparable monitor located at sea level. It is essential to have reliable high counting rate detectors at mid latitude locations so that spectral characteristics of each event can be determined.

Care must be taken when comparing data from different stations since three factors must be considered: vertical cutoff rigidity, altitude and spatial anisotropy of the incoming particle flux. This is evident during the extremely anisotropic event on 24 May 1990 when the Oulu, Finland detector recorded a broad maximum with a 6.9% increase (Kananen, et al., 1991) while the Lomnicky Stit monitor recorded a definitive five-minute maximum of 6.5% as illustrated in Figure 2. Once the altitude correction is applied, these data can be used for anisotropy evaluations.

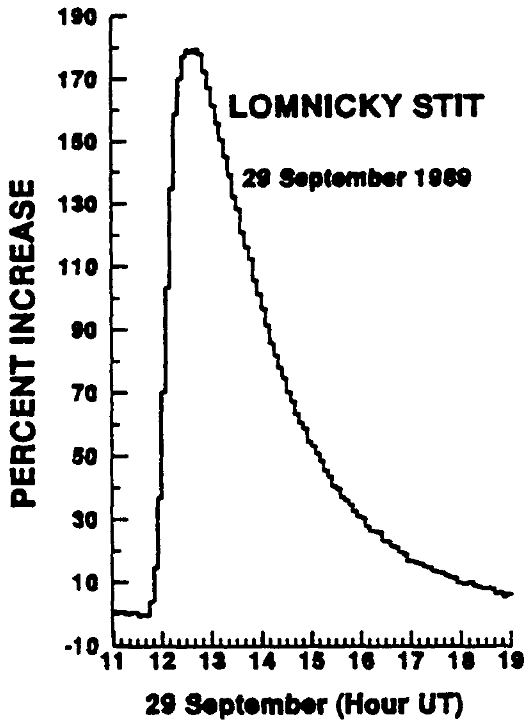

Figure 1. Cosmic ray intensity recorded at Lomnicky Stit during the GLE on 29 September 1989.

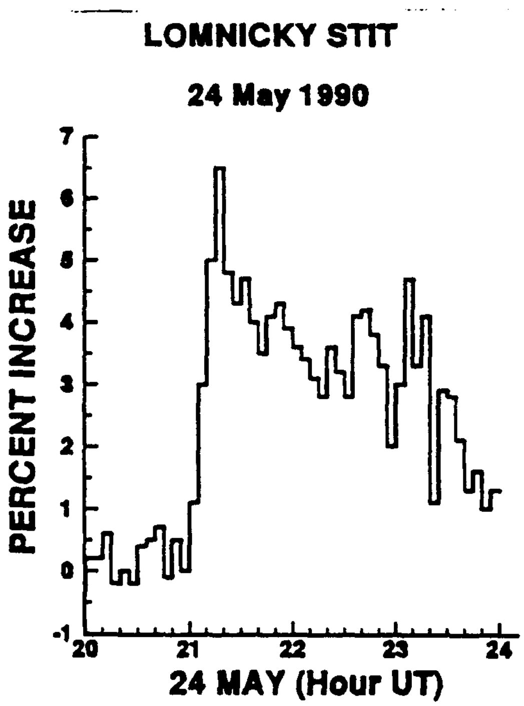

Figure 2. Cosmic ray intensity recorded at Lomnicky Stit during the GLE on 24 May 1990.

3. MISSING DATA AND THE EVENTS OF THE 19TH SOLAR CYCLE

For a variety of reasons we have been unable to locate small-time interval data for several of the events. Although 10 and 15-minute data were available in some selected cases and five-minute data since 1972, these data were not routinely exchanged except upon special request. Cosmic ray scientists having GLE archives are requested to inspect their records to see if some of the

missing data can be located. The footnotes in Table 1 identify those events for which only hourly, or bi-hourly, data are in the GLE database.

Eight GLEs were reported between 1956 and 1961; several of these, particularly those in November 1960, should have been observed by the Lomnicky Stit IGY monitor. We have located a limited amount of data for three of these events, primarily from personal archives. Again, scientists are requested to search their archives and forward to us any Lomnicky Stit data they find for any of the GLEs in the 19th solar cycle.

4. STUDIES USING THE LOMNICKY STIT DATA

The value of having two reliable stations in close proximity to each other such as the Lomnicky Stit and the Jungfraujoch monitors was clearly evident with the first report of a solar neutron response during the solar flare on 3 June 1982 (Efimov, et al., 1983; Debrunner et al., 1983). The Lomnicky Stit data were extremely important for confirming other simultaneous observations at Jungfraujoch, Switzerland (at 3475 meters) and Rome, Italy (at sea level), since the increase above the background in the 5-minute data was at the 9-sigma level.

As a direct result of the identification of the solar neutron event, an analysis of the count rate at Lomnicky Stit during 17 solar flares with solar gamma or hard X-ray emissions during 1980-1985 was undertaken. While for the whole amount of data the superimposed epoch analysis did not give any significant increase in the five-minute averages close to the maximum of the gamma/X-ray emission, a slight increase was noted when there were flares at large heliocentric angles from the solar central meridian (5 cases). This result may indicate anisotropic production of neutrons preferentially traveling to the earth from the near-limb flares (Kudela, 1990). This result needs confirmation or rejection from similar studies using larger amounts of data from different high altitude neutron monitors.

5. SUMMARY

This is the second preliminary list in which we have tried to summarize the key parameters associated with the ground-level events recorded by one specific neutron monitor. Since many of the key features of ground-level events require data from several stations, we hope that data from other stations will be assembled in a similar way so that a complete and comprehensive data base can be compiled for each of these unique events.

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